



**GRC · 2014**

## LUROVA - From Render Engine to Thermal Model

Ron Creel

Apollo Lunar Roving Vehicle Team Member



**Apollo Rover on the Moon**

Thermal & Fluids Analysis Workshop  
TFAWS 2014

August 4 - 8, 2014

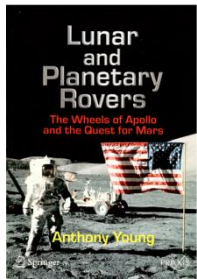
NASA Glenn Research Center  
Cleveland, OH



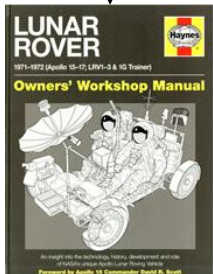
# LUROVA Introduced at TFAWS-2006



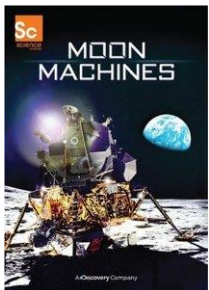
- Full Interactive Mission Support Thermal Model Needed for LUROVA Book and STEM Challenge Simulation for Students



Previous  
Books



Movie





## Lunar ROVing Adventure - LUROVA

*"Edutainment" Simulation*







Plan



Prepare



Perform



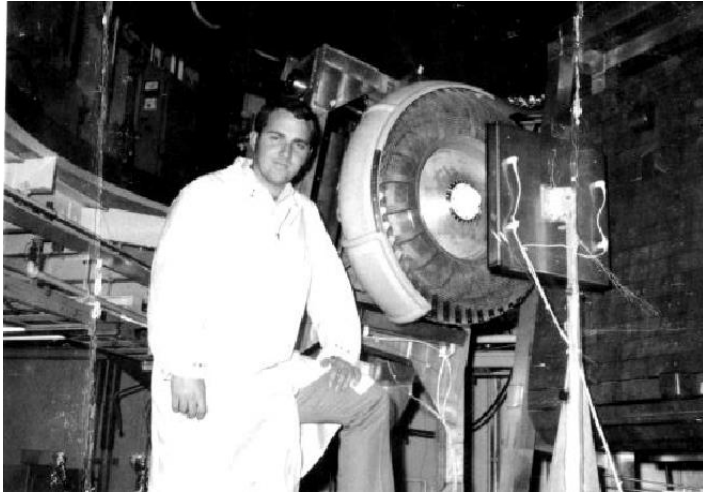
Post-Traverse



DVD for  
LUROVA  
Book



Rotating  
Rendered  
Rover  
Model

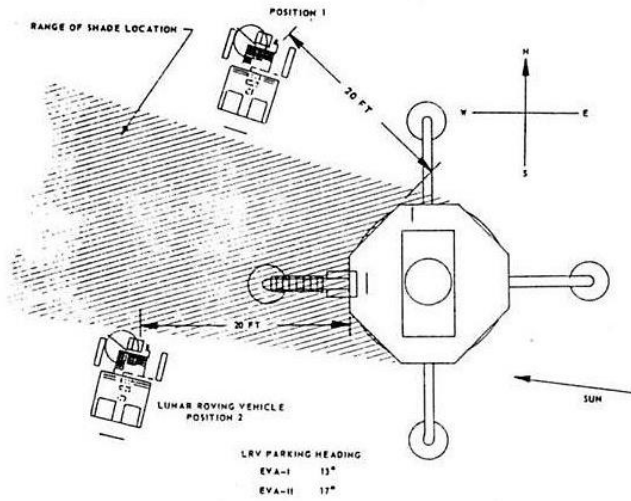


**Mobility Subsystem TVAC Testing**

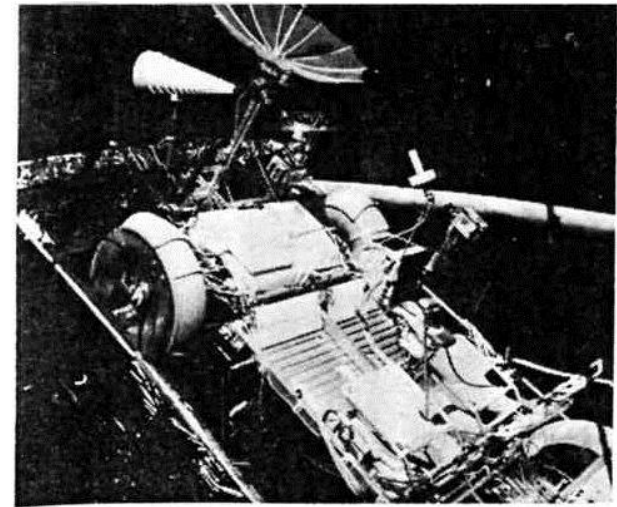
- 177 Node “Full” Model Correlated with TVAC Testing
- Separate Forward, Center, and Aft Section Models Required Due to LOHARP 140 Surface Node Limit



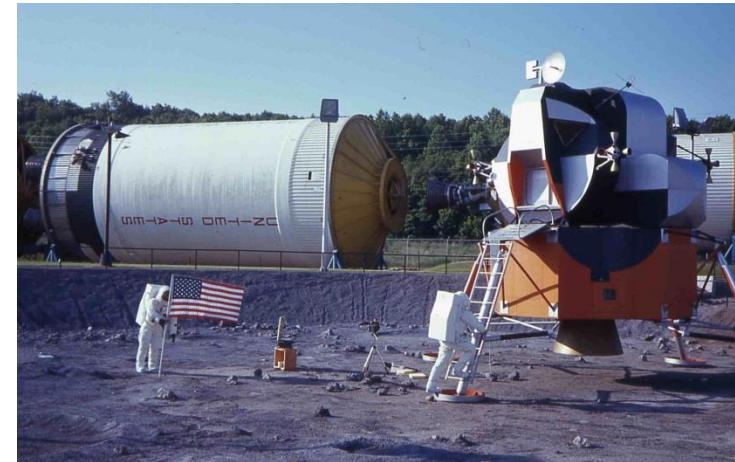
- 19 Node Forward Chassis Batteries and Electronics Model Developed for Responsive Mission Support



**LOHARP Calculated View Factors and “Wireframe” Verification Plots**



**Qualification and Flight Units TVAC**

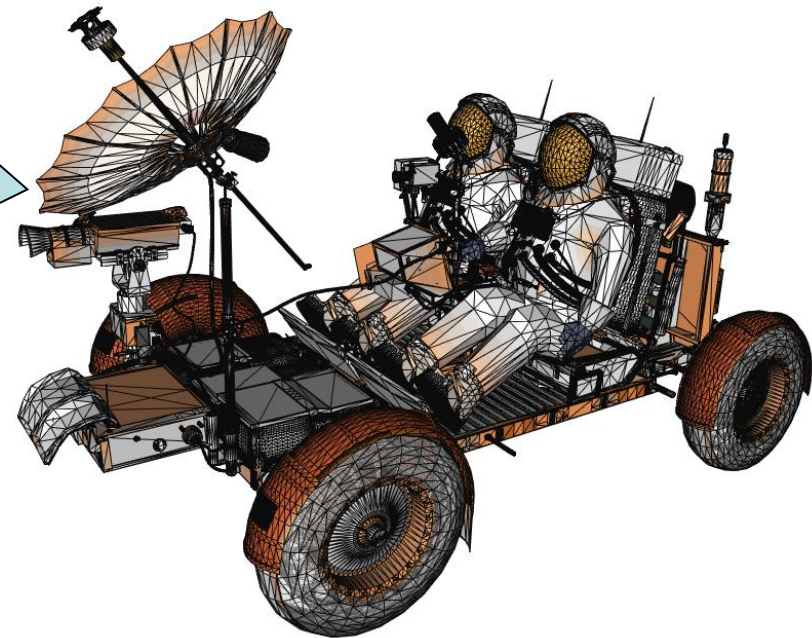
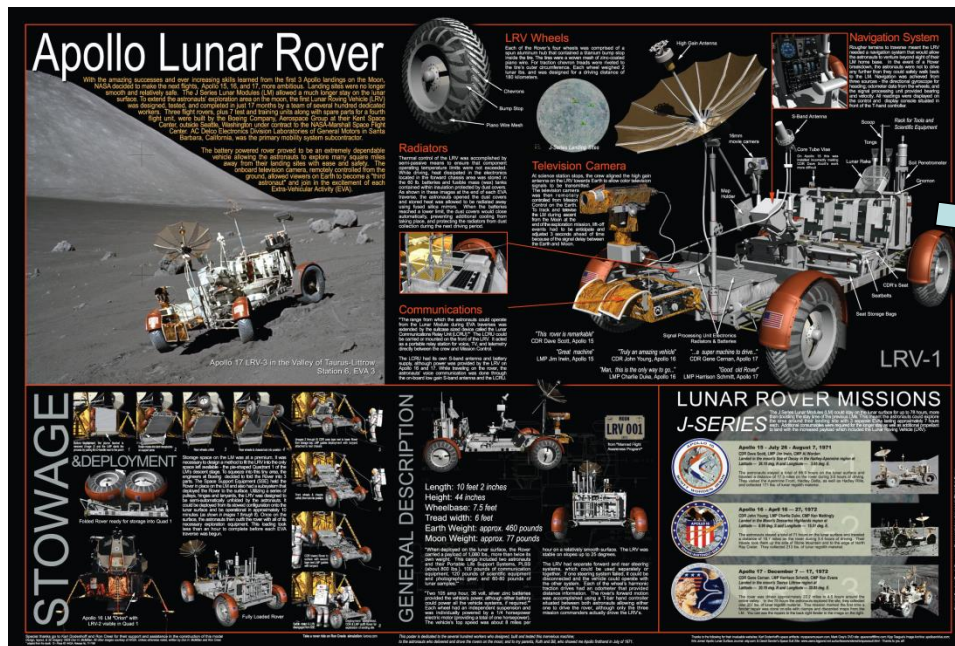


**View Factor Verification using Full Scale LM Model at U.S. Space and Rocket Center**



# Render Engine Provides High Quality Surface Data

- Original “Full” Rover Thermal Model Nodes and Linear Conductors Located, But No Surface Model for Radiation Conductors and Heat Rates
- Candidate “Lightwave” Rendered Polygons Used for Rover Poster



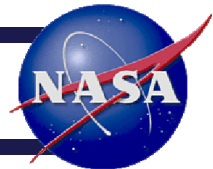
**Rover 3D Model and Poster Created by Don McMillan**

**911,509 Surface Polygons with  
489,731 Vertices**

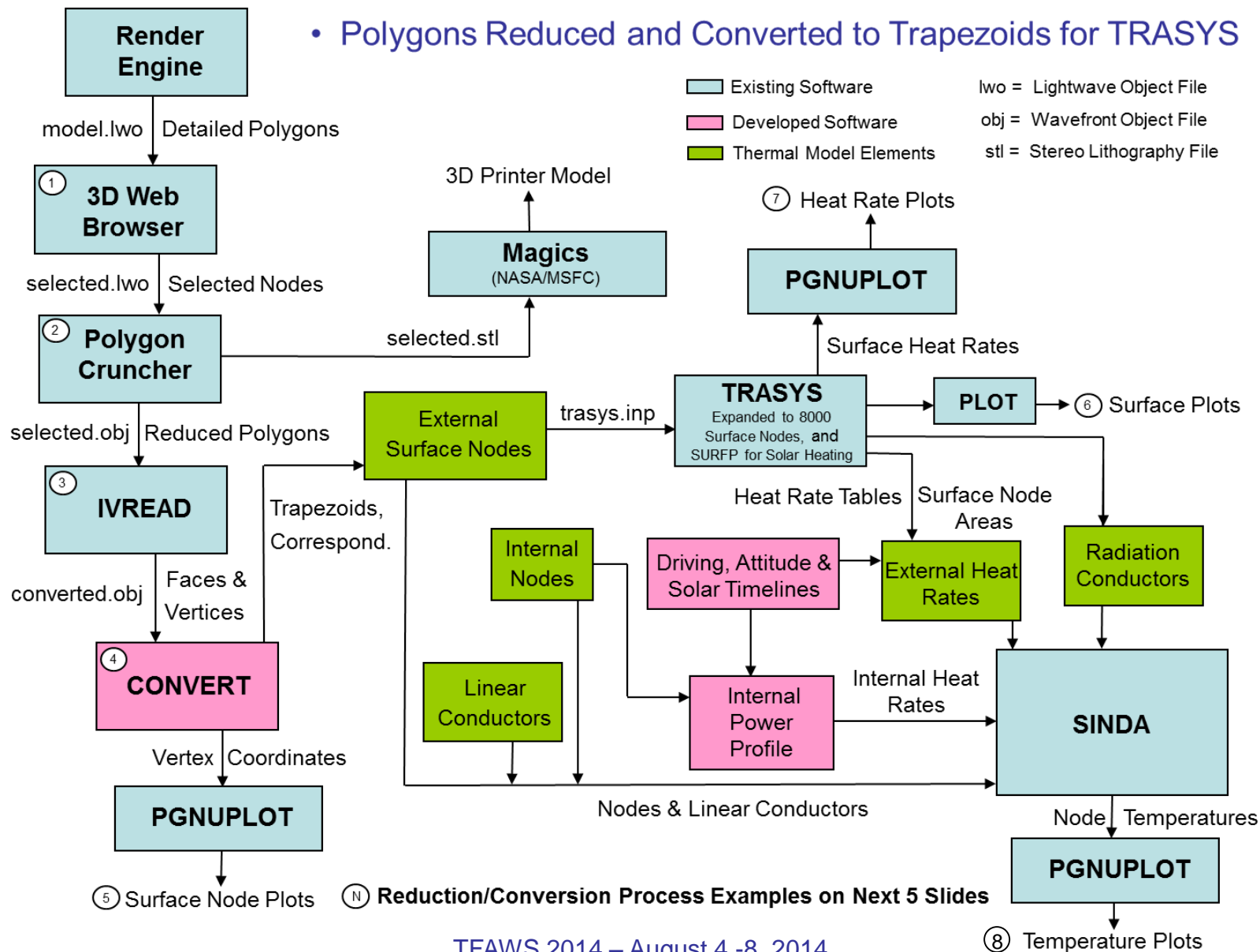
- Too Many Polygon Surfaces for TRASYS 4000 Node Limit



# Polygon Reduction/Conversion (R/C) Process Developed



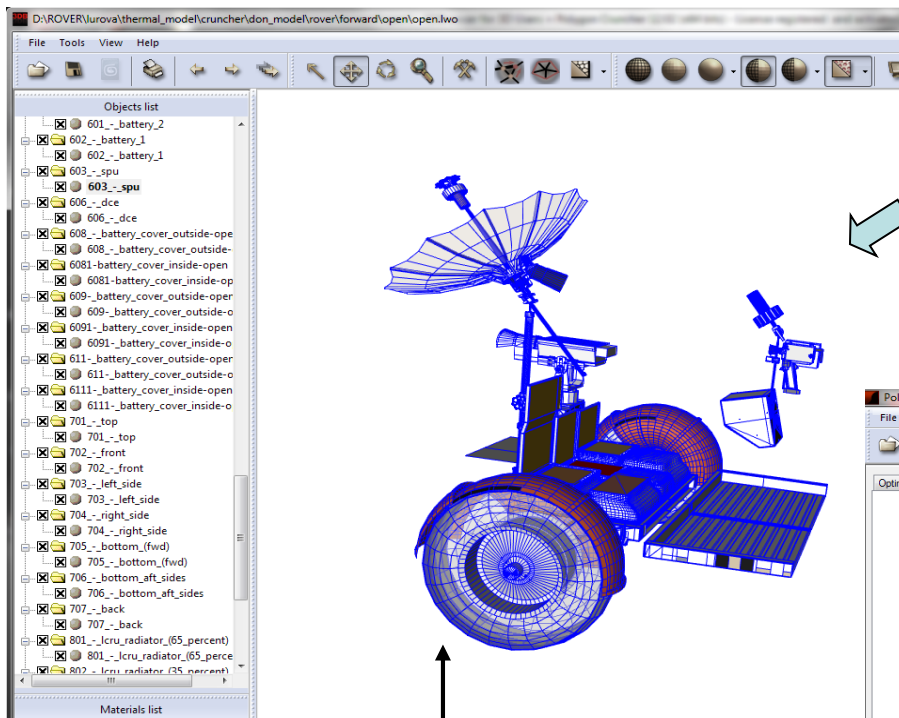
- Polygons Reduced and Converted to Trapezoids for TRASYS





# Polygon Reduction Steps & Products

- Render Engine Polygons Selected and Reduced for Forward Chassis Thermal Model

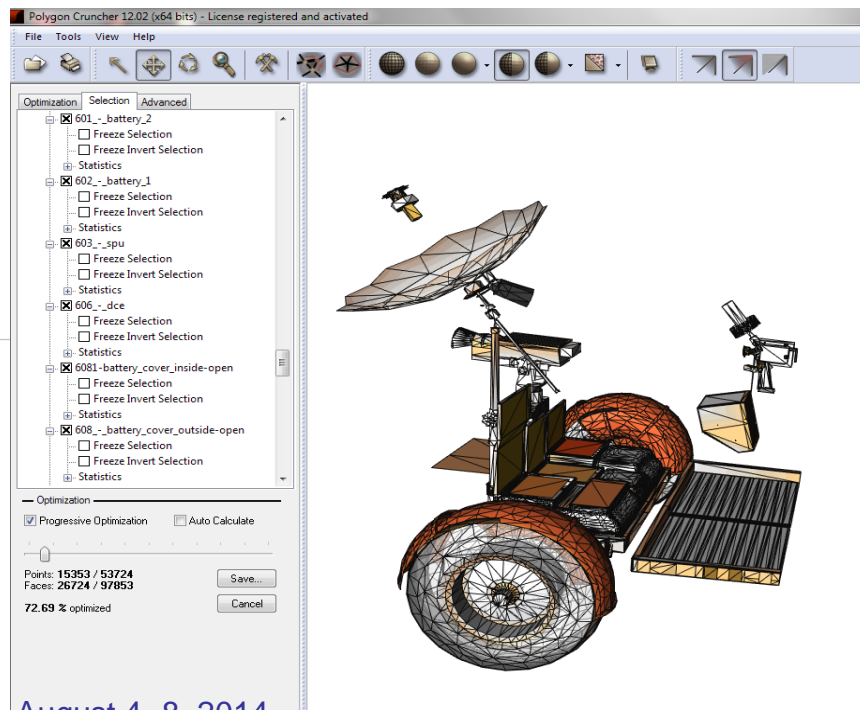
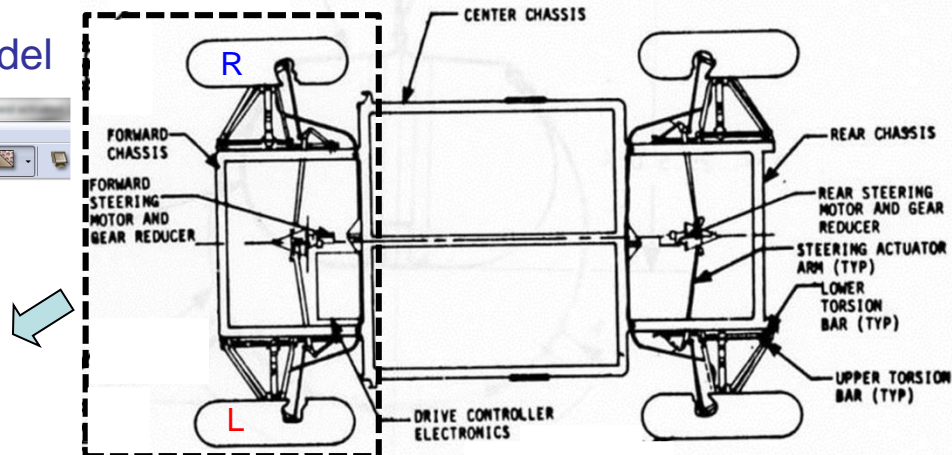


1

3D Web Browser Used to Select Forward Chassis Model Nodes

2

Polygon Cruncher Used to Reduce Number of Triangular Polygons



TFAWS 2014 – August 4 -8, 2014



# Triangular Polygons Converted to TRASYS Trapezoids



**Input**

```
Administrator: Command Prompt - ivread_2006
Microsoft Windows [Version 6.1.7601
Copyright (c) 2009 Microsoft Corpor
C:\Users\Ron>cd
D:\>cd rover
D:\>ROVER\lurova
D:\>ROVER\lurova\cd thermal_model
D:\>ROVER\lurova\thermal_model\cd cruncher
D:\>ROVER\lurova\thermal_model\cruncher>ivread_2006
3 July 2014 6:32:52.014 PM
ello: This is IVRead,
a program which can convert some files from
some 3D graphics format to some others:
".ase" 3D Studio Max ASCII export;
".bun" Movie BVH surface geometry;
".dxf" AutoCAD DXF;
".hnc" Softimage hierarchy;
".io" SGI Open Inventor;
".obj" Wavefront Advanced Visualizer;
".off" Geomview OFF file;
".oogl" OOGI file (input only);
".pov" Persistence of Vision output only;
".ps" PostScript (output only) (NOT READY);
".smf" Michael Garland's format;
".stl" ASCII Stereolithography;
".tec" ASCII Stereolithography;
".tri" IGreg Hood triangles, ASCII;
".tria" IGreg Hood triangles, ASCII;
".ts" Mathematica ThreeScript (output only);
".txt" Text (output only);
".ucd" AUS unstructured cell data (output only);
".vla" VLA (points and lines);
".vml" VML;
".xgl" XGL (output only) (DEVELOPMENT);
".xyz" XYZ (points and lines);

Current limits:
500000 points;
500000 line items;
500000 faces.

60 vertices per face;
100000 points to display;
2000 materials;
1000 textures.
```

**Output**

```
Administrator: Command Prompt
3 July 2014 6:33:35.044 PM
BJ_READ - Read 8726 text lines from 701.obj
ATA_REPORT - The input file contains:
Bad data items 0
Text lines 8726
Duplicate points 0
Faces 4240
Groups 1
Vertices per face, maximum 4
Line items 0
Materials 4469
Objects 0
BJ_WRITE - Wrote 25667 text lines to 701_out.obj
IVREAD:
Normal end of execution.
3 July 2014 6:31:36.042 PM
D:\>ROVER\lurova\thermal_model\cruncher>
```

**701\_out.obj - Notepad**

```
File Edit Format View Help
# 701_out.obj created by IVREAD.
# Original data in 701.obj.

g Group001

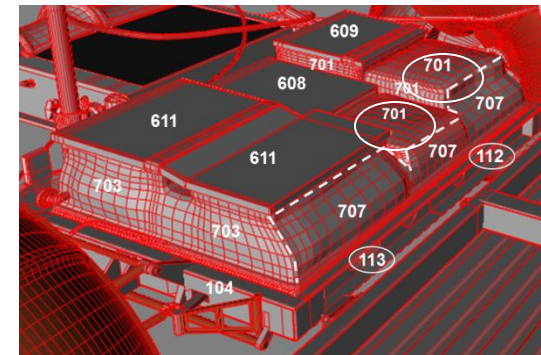
v 0.185530 -0.639192 -0.355888 1.00000
v 0.187721 -0.649190 -0.357875 1.00000
v 0.185650 -0.647000 -0.363044 1.00000
v 0.183367 -0.638798 -0.362232 1.00000

.....

f 4/1 3/2 2/3 1/4
f 3/5 6/6 5/7 2/8
f 6/9 8/10 7/11 5/12
f 1/13 2/14 10/15 9/16
f 2/17 5/18 11/19 10/20
f 5/21 7/22 12/23 11/24
f 9/25 10/26 14/27 13/28
f 10/29 11/30 15/31 14/32
f 11/33 12/34 16/35 15/36
f 15/37 16/38 17/39

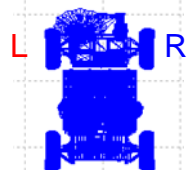
.....|
```

3 IVREAD Converts Reduced Polygon "Faces" and "Vertices" to ".obj" Readable Ascii Format



Forward Chassis Surface Model

4 CONVERT Provides TRASYS Trapezoids for Calculating Radiation Conductors, and Correspondence to Combine Polygons for Surface Nodes Heat Rates, and Areas, Allows Mirroring for Symmetrical Mobility Subsystems and Coordinate Rotations for Variable Solar Orientation

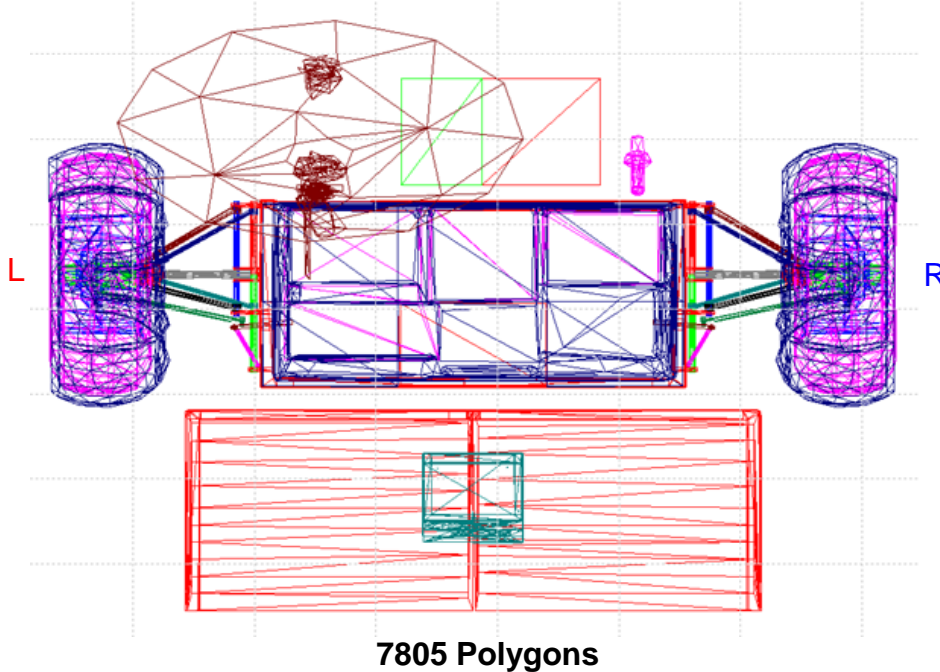


```
HEADER OPTIONS DATA
TITLE LUROVA
MODEL = LUROVA
RSO

HEADER SURFACE DATA
S
SURFN = 601001
TYPE = TRAP
ACTIVE = TOP
PROP = 0.90, 0.90
P1 = -0.46338487, -3.09466863, -0.89315426
P2 = -1.28817642, -2.37285924, -0.89315426
P3 = -1.28817642, -3.09466863, -0.89315426
P4 = -0.46338487, -3.09466863, -0.89315426
NNAX = 1
NNY = 1
S
SURFN = 601002
TYPE = TRAP
ACTIVE = TOP
PROP = 0.90, 0.90
P1 = -0.46338487, -2.37285924, -0.89315426
P2 = -1.28817642, -2.37285924, -0.89315426
P3 = -0.46338487, -3.09466863, -0.89315426
P4 = -0.46338487, -2.37285924, -0.89315426
NNAX = 1
NNY = 1
S
SURFN = 602001
TYPE = TRAP
ACTIVE = TOP
PROP = 0.90, 0.90
P1 = 0.75579894, -2.38128114, -0.94096255
P2 = 1.61763108, -3.08834314, -0.94096255
P3 = 1.61763108, -2.38128114, -0.94096255
P4 = 0.75579894, -2.38128114, -0.94096255
NNAX = 1
NNY = 1
```

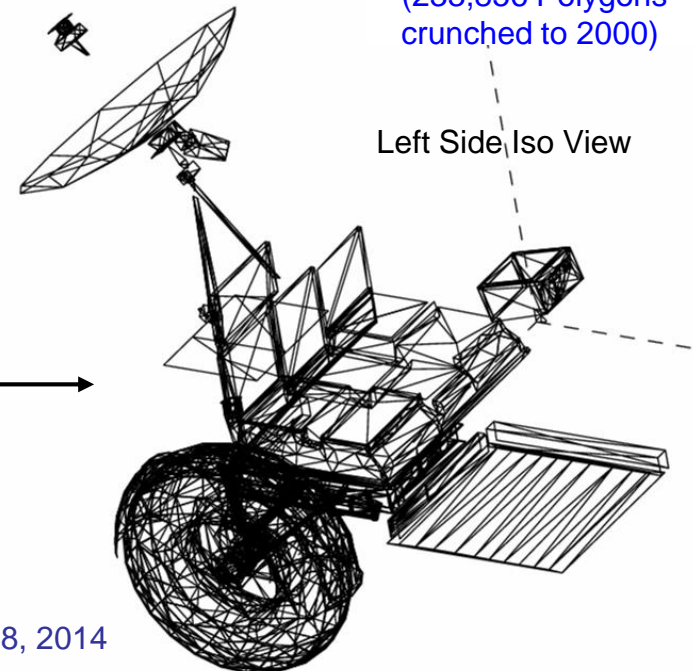
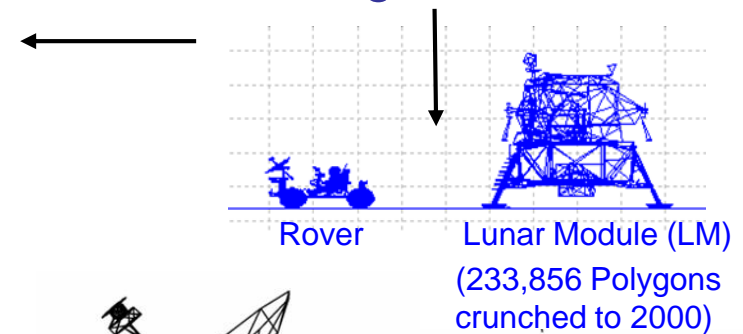
```
HEADER CORRESPONDENCE DATA
FIG LUROVA
601 =
601001, 601002
602 =
602001, 602002
603 =
603001, 603002
606 =
606001, 606002, 606003, 606004
608 =
608001, 608002, 608003, 608004, 608005, 608006, 608007,
608008, 608009, 608010
609 =
609001, 609002, 609003, 609004, 609005, 609006, 609007,
609008, 609009, 609010, 609011, 609012, 609013, 609014,
609015, 609016, 609017, 609018, 609019, 609020, 609021,
609022, 609023, 609024, 609025, 609026, 609027, 609028,
609029, 609030, 609031, 609032, 609033, 609034, 609035,
609036, 609037, 609038, 609039, 609040, 609041, 609042
610 =
610001, 610002, 610003, 610004, 610005, 610006, 610007,
610008, 610009, 610010, 610011, 610012, 610013, 610014,
610015, 610016, 610017, 610018, 610019, 610020, 610021,
610022, 610023, 610024, 610025, 610026, 610027, 610028,
610029, 610030, 610031, 610032, 610033, 610034, 610035
```

- Surface Plot Programs Provide Visual Verification for R/C Processed Forward Chassis Surface Nodes



- 6
- Converted Surface Trapezoids  
using TRASYS PLOT

- 5
- Polygon Faces and Vertices  
using PGNUPLOT





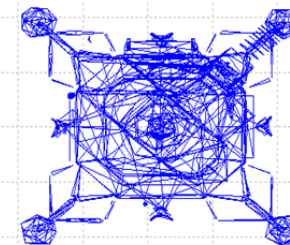
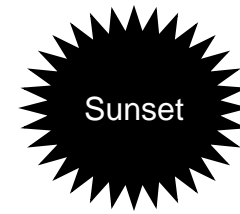
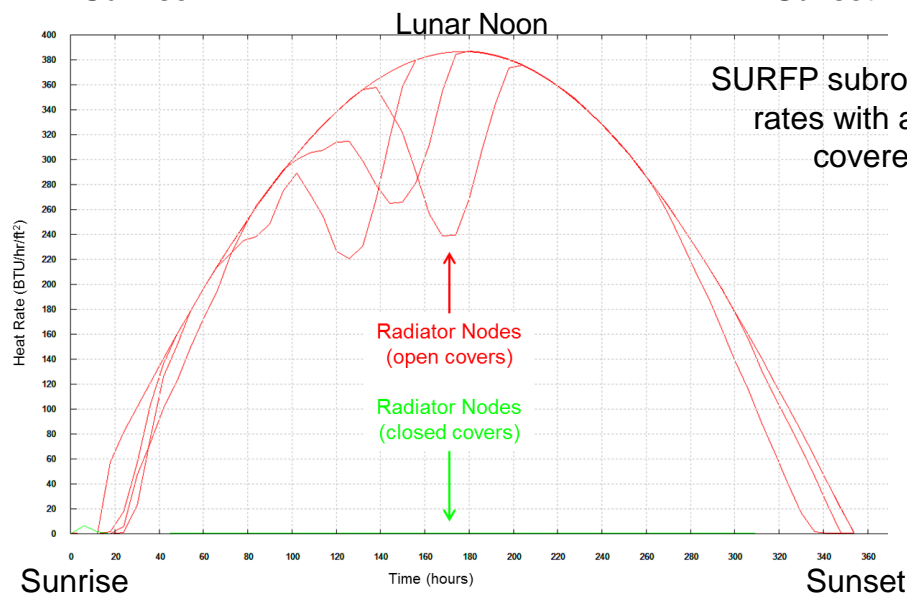
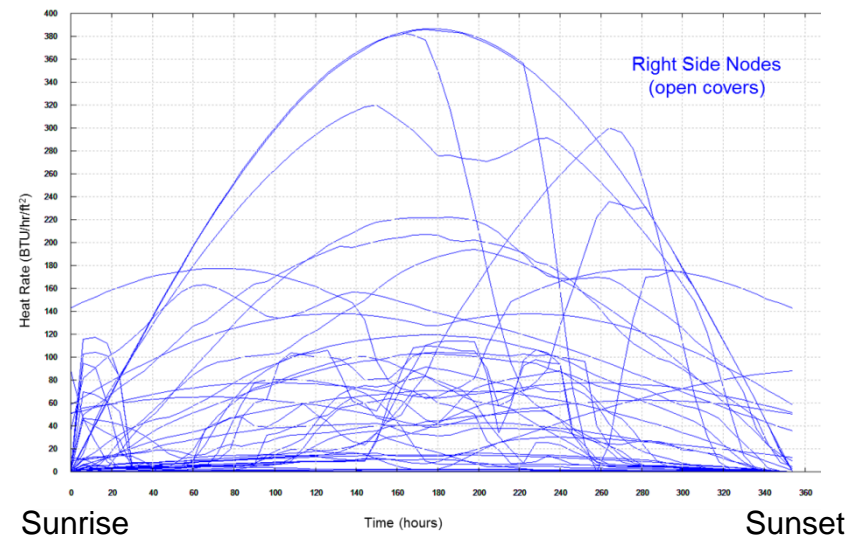
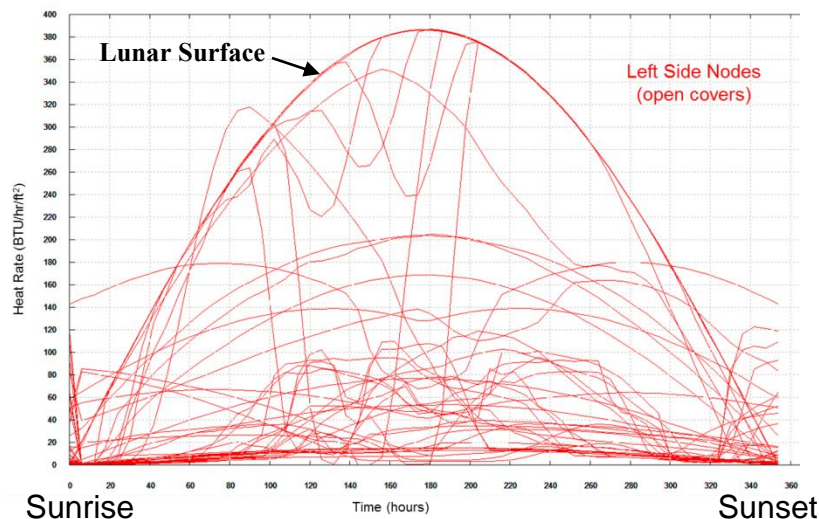


# R/C Process Heat Rates Comparison



- TRASYS Calculated Forward Chassis Node Heat Rates Verified

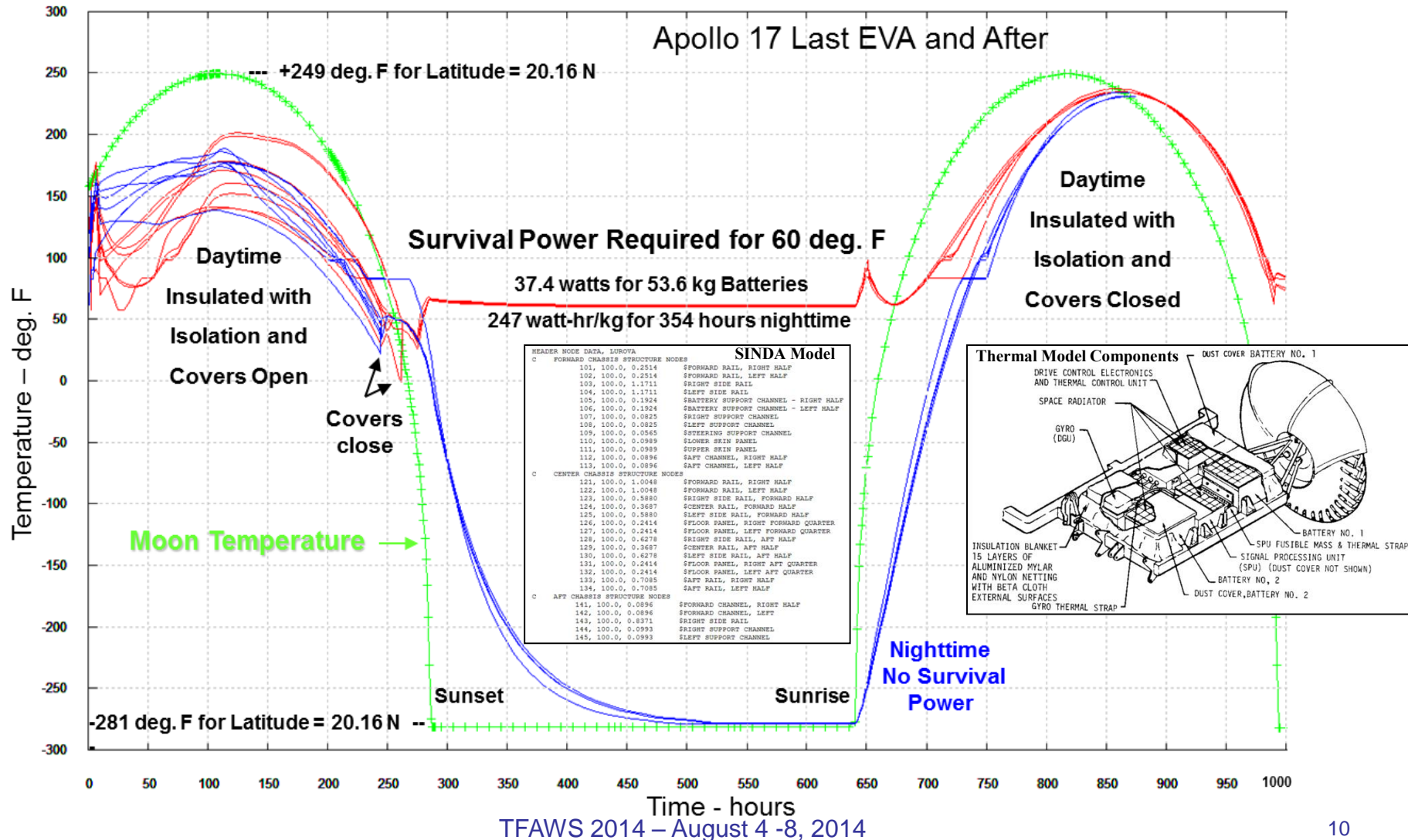
7



Lunar Module (LM)

8

- Next Step is to Compile SINDA Model to Compare with 19 Node Mission Model
- Recently Used for NASA Nightrover Centennial Challenge for Energy Storage





# Future Plans for LUROVA

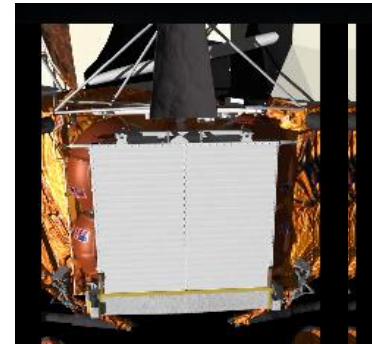


- Use Successful R/C Process to Add Rover Center and Aft Model Sections
- Complete Interactive SINDA Thermal Model for Book and DVD Simulation
  - Driving with Astronauts, and Parked with Covers Closed/Open and LM
- Use R/C Process for LM/CSM Transportation Phase Model

Passive  
Thermal Control  
(PTC)  
“Barbeque”  
Rotation  
(3 revs/hr)



338,417 Polygons

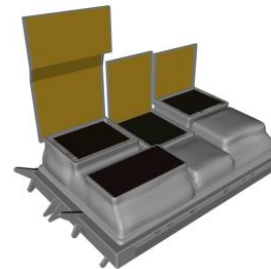


PTC - Solar  
Heating  
Simulation



- Expand “Additive Manufacturing” 3D Model for Student Awards

NASA/MSFC Sponsoring  
3D Printer for ISS  
Experiments



Printed Rover Forward  
Chassis Model  
Created Using MSFC  
3D Printer

- Continue STEM Student Lectures and Support to Human Exploration Rover Challenge (formerly Moonbuggy Races)